

2023 Vehicle Technologies
Annual Merit Review
June 12–15, 2023

Guidelines
R&D Posters

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Changes at a Glance for 2023

- All posters must be uploaded through [this Google Form](#) no later than **APRIL 14, 2023**.
- For **reviewed** posters, PIs must record a 5-7 minute presentation and upload the video through [this Google Form](#). The videos will be available on demand for reviewers only. All video recordings are due no later than **APRIL 28, 2023**.
- There will be no poster session. For reviewed posters, reviewers will reach out directly to PIs with any questions or comments. PIs must look for and be responsive to reviewer emails from June 12-June 30.
- The AMR will be virtual.

Submission Deadline

Poster presentations must be uploaded no later than

APRIL 14, 2023.

Poster recordings must be uploaded no later than

APRIL 28, 2023.

No exceptions.

Legal Indemnification

FOR INFORMATION ONLY. **DO NOT INCLUDE IN PRESENTATION.**

By submitting a presentation file to Oak Ridge Institute for Science and Education (ORISE) for use at the U.S. Department of Energy's (DOE's) Vehicle Technologies Office Annual Merit Review Meeting and to be provided as hand-out materials, and posting on the DOE's website, except for employees of the Federal Government and DOE laboratory managing and operating contractors, the presentation authors and the organizations they represent agree to defend, indemnify and hold harmless ORISE, its officers, employees, consultants and subcontractors, and the DOE from and against any and all claims, losses, liabilities or expenses which may arise, in whole or in part, from the improper use, misuse, unauthorized use or disclosure, or misrepresentation of any intellectual property claimed by others. Such intellectual property includes copyrighted material, including documents, logos, photos, scripts, software, and videos or animations of any type; trademarks; service marks; patents; and proprietary, or confidential information.

Employees of Federal Government agencies and DOE laboratory managing and operating contractors collectively represent and warrant that they have acquired the rights and/or permission for use of all intellectual property, as listed above and claimed by others, that is needed for developing and submitting a presentation file to ORISE for use at the DOE's Vehicle Technologies Office Annual Merit Review Meeting, and to be provided as hand-out materials, and posted on the DOE's website.

Creating Your Poster Files

- Your poster is public and will be posted to the DOE Vehicle Technologies Office (VTO) Annual Merit Review (AMR) website.
- You are required to create the following file:
 - A Microsoft PowerPoint file following the instructions and guidelines contained within this PowerPoint template.
 - Once your PowerPoint presentation is complete, you must create a PDF version of your PowerPoint presentation following the instructions in this document.
- You may design your slides on either a PC or a Mac.
- **Naming your files:** Use the file name that ORAU sent you in your presentation request email to name your electronic PowerPoint and Adobe files:

Proj#_PI LastName_2023_p

Example: ACE002_smith_2023_p

Formatting Your Poster

- **Format:** Use a 16:9 format
- **Font:**
 - Do not use proprietary fonts. All fonts in the presentation must be standard across Windows and Mac platforms or information may be lost when creating the Adobe PDF version of your presentation. Use only Arial, Times New Roman, Courier New, Verdana, or Trebuchet MS.
 - Use at least a 12-point font.

Formatting Your Poster (Continued)

- Ensure there is high contrast between text and background for best readability. We recommend a white background along with black or dark text. Light or gray text is hard to read so adjust your template accordingly.
- Please remove any copyright indicia from your company template so that your poster can be posted on the AMR website.
- Spell out acronyms and chemical formulas the first time that you use them.
- Add Alt Text to all graphics, tables, and charts.
- Fill out the Properties box for your presentation.

Adding Images to Your Poster

- Do not copy/paste images into your presentation.
 - On PC: Insert the image using the “Insert/Picture/File name” menu option rather than copying/pasting.
 - On Mac: Insert the image using “Insert/Picture/Picture From File” menu option rather than copying/pasting.
- Crop images in an image processing software. Save the images as an external file (.jpg and .png file formats work well).
- Inserting original images into your presentation works best for preserving image clarity. If originals are not available, it may be an indication the image is copyrighted.

Animations and Videos

- Be aware that animations do not convert to PDF and animated information may not be visible to reviewers or in the final PDF posted on the VTO AMR website.
- Videos do not translate to PDF reliably and will not be posted on the VTO AMR website.

Content Restrictions

- Your presentation is public and will be posted on the VTO AMR website.
- You must include the phrase “This presentation does not contain any proprietary, confidential, or otherwise restricted information” on at least the first slide (you may put on all slides if you wish).
- Do not include any proprietary or confidential information. It is your responsibility to ensure that any subcontractor information is not proprietary or confidential.
- You must remove the copyright indicia on your company template if that indicia is part of the template; otherwise, we cannot post your presentation on the VTO AMR website.
- Your presentation may **not** include any slide that has “Official Use Only” or “Sensitive” or any similar wording, or information that your organization might construe as being in such categories.
- You must include the phrase “Any proposed future work is subject to change based on funding levels.” on all slides with future-looking statements.

Copyright Restrictions

- If you use any copyrighted information or graphics or intellectual property, it must be properly attributed.
- Do not assume subcontractor information may be used without their approval.
- Do not assume that information or images published on a website can be used without permission.
- If you use copyrighted graphics (including copyrighted photos and journal and magazine covers), you must provide written permission along with your submitted file for it to be accepted by DOE for the purposes of the AMR.
- Intellectual property includes copyrighted material, including documents, logos, photos, scripts, software, and videos or animations of any type; trademarks; service marks; patents; and proprietary or confidential information.
- Also see the indemnification statement on p. 7.

Use of Logos

- **Do NOT** use the DOE logo or seal in your presentation. Some examples include:



- **Do NOT** use the EERE slide template.
- If you use corporate logos for organizations other than your own, secure permission for use.

Recommended Slide Order

- **Title Slide:** must include Project ID, name of principal investigator, name of presenter if different, and “This presentation does not contain any proprietary, confidential, or otherwise restricted information.”
- **Overview Slide:** must include timeline, budget, barriers, and partners
- **Relevance**
- Milestones (if not included as part of Approach)
- **Approach**
- **Technical Accomplishments and Progress**
- Responses to Previous Year Reviewers’ Comments
- **Collaboration and Coordination with Other Institutions**
- Remaining Challenges and Barriers
- **Proposed Future Research**
- **Summary Slide**

You are strongly encouraged to include the slides in bold.

Posters

- Posters are **due no later than April 14, 2023.**
- Posters can be formatted as a complete slide deck or as one poster.
- Poster file formatting:
 - You must submit a .pdf version of your poster
 - Use a 16:9 aspect ratio for best viewing
 - Do not use a transparent background
- Upload your file through [this Google Form](#).
- **There will be no poster session. For reviewed posters:**
 - Reviewers will be contacting PIs directly via email with any questions. PIs must look for and be responsive to reviewer emails from June 12-June 30.
 - Poster presentations must be recorded and will be available on demand during AMR. Your poster presentation recording should be between 5-7 minutes. Upload your video recording [through this Google Form](#).

Late Information Addition

- Information and research updates that become available following the submission of the presentation but before the AMR may be supplied in response to questions submitted via email.
- **No extensions will be granted for poster submission.**
- Any additional information must still adhere to the time limitations.

Preparing your PowerPoint for Web-Publication/PDF

If making your poster in PowerPoint, make sure to create your web-ready PDF file (the file that will be published on the VTO AMR website) using the following instructions on the next pages (p. 20-25) to:

- Add Alt Text
- Add presentation detail information
- Create and verify the final PDF

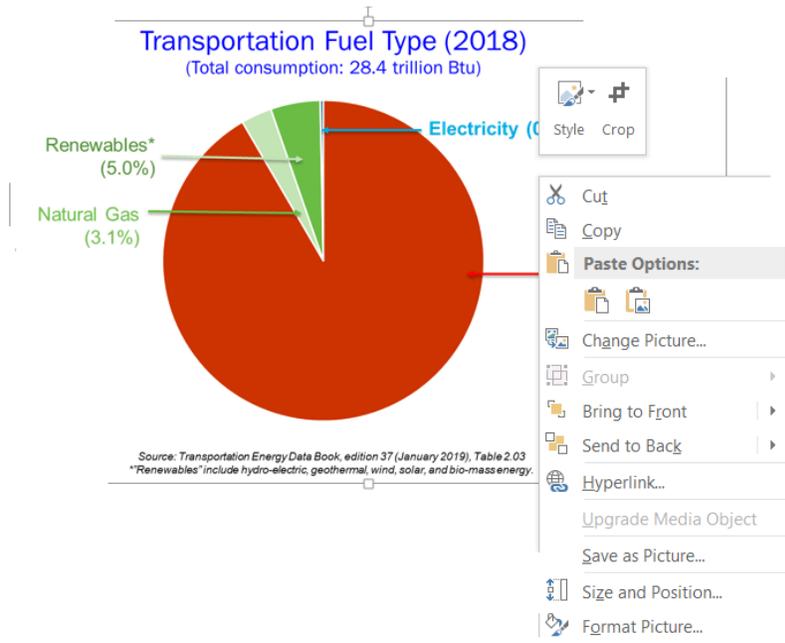
Adding Alt Text to Your Presentation

- You must add alternate text (Alt Text) to key graphics, charts, and tables on each slide.
- Alt Text helps visually impaired people who use screen readers to know what the picture shows.
- Be accurate and succinct. You do not have to say “image of...” or “graphic of...”
- A good Alt-Text example of a picture of a crowd at a basketball game:

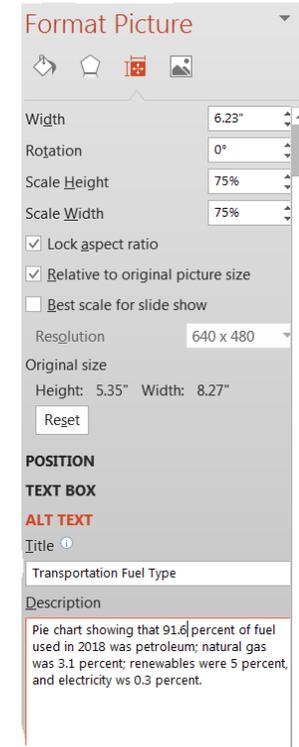
“A large, diverse group of cheering students, standing up, and fist-pumping on the bleachers of a basketball game.”

To Add Alt Text to a Chart, Graph, or Image

Note: These instructions are for PowerPoint 2013. If you have a newer version, you may be able to right click on the graph or chart and select “Edit Alt Text” directly from the menu.



1. Right click on the graph or chart and select “Size and Position...”



2. Select the “Alt Text” option and enter the **Title** and a short brief **Description** of the chart

3. Close the Format Picture pane to return to the PowerPoint slide

Adding Presentation Detail Information

- Under the **File** tab, select **Info**
- Click on “**Properties**” and then select “**Advanced Properties**”

On the “**Summary**” tab of the pop-up window, complete the following fields:

- **Title:** Enter the title of your presentation
- **Subject:** Substitute your **Project ID** into the subject
- **Author:** Enter the **PI Name** and **Company**

- **Save preview picture:** Make sure this box is checked
- Press **OK**

The screenshot shows the Microsoft PowerPoint interface. On the left is the File tab ribbon with the 'Info' button highlighted. The main area displays the 'Info' tab for a presentation titled '2021 RD instructions (003) LS (002)'. A 'Properties' dropdown menu is open, showing 'Advanced Properties' selected. A red arrow points from the 'Advanced Properties' option to the '2021 RD instructions (003)_LS_LR.pptx Properties' dialog box. The dialog box has tabs for 'General', 'Summary', 'Statistics', 'Contents', and 'Custom'. The 'Summary' tab is active, showing fields for Title, Subject, Author, Manager, Company, Category, Keywords, Comments, Hyperlink base, and Template. The 'Save preview picture' checkbox is checked. Red arrows point from the instructions to the corresponding fields in the dialog box: 'Oral Presentation Guidelines and Examples' for Title, 'Project ID, 2021 VTO Annual Merit Review' for Subject, and 'Principal Investigator Name, Company' for Author. A red arrow also points from the 'OK' button in the dialog box to the 'Press OK' instruction in the text.

Creating Final Version of Your Poster (if using PowerPoint)

- Once your PowerPoint presentation is final, you must minimize your PowerPoint's file size.
- Do this by using the “**Save As**” option to save the final version of your file as a PowerPoint presentation.
- Doing a simple “Save” command will not minimize file size.
- You can “Save As” an existing PowerPoint filename if needed.

Creating PDF Version of Your Presentation

- You are required to submit a PDF version of your presentation.
- After saving your PowerPoint file using the “Save As” option, save the file as a PDF using the same naming conventions as your PowerPoint file.
 - If you have Adobe Acrobat Pro software, you can use the Acrobat PowerPoint plug-in or select “Save As Adobe PDF” to create your PDF.
 - If you do not have Acrobat Pro, click “Save As” and select “PDF” from the Save As type menu.
- Click the “Options” button in the Save As window and make sure to check the box to enable accessibility tags. Look for text that says “Document structure tags for accessibility” or “Enable accessibility and reflow with tagged Adobe PDF.”
- Click “Save”.
- Select “NO” if asked if you would like to convert the presentation’s speaker notes to text annotations in the PDF.

Verifying PDF File

After you create the PDF,

- Scroll through the document and look at every page to ensure the PDF matches the PowerPoint file.
- Look for missing items from charts, such as legends and axis titles, which sometimes disappear due to incorrect object reordering that can result from the tagging process for accessibility.
- If you do find issues that you're not able to fix, a communications or publishing specialist at your organization may be able to help. Or, you can contact VTAMR@ORAU.org to help troubleshoot the PDF conversion.

R&D Evaluation Criteria

All R&D posters follow the same content and design guidelines for reviewer scoring.

Criterion	Weight
Relevance	Adequate/Inadequate
Approach	25%
Technical accomplishments	50%
Collaborations and coordination with other institutions	12.5%
Proposed future research	12.5%
Resources	Adequate/Inadequate

Consider these criteria and weights when creating your poster!

Slide Titles and Key Results

- **Slide Titles:** Except for the mandatory Title, Overview, and Summary slides, all slide titles and headings should relate directly to the evaluation criteria.
- **Key Results:** The key take-home message for each results slide should be communicated as a banner, header, or bullet.

Instructions for Specific Slides

- The following guidelines provide specific information on mandatory slides and the type of information expected within the criteria guidelines.
- **Your presentation should include:**
 - **Title Slide** (mandatory)
 - **Overview Slide** (mandatory)
 - **Review Criterion Slides** (mandatory, one or more slides as appropriate for each review criterion)
 - **Summary Slide** (mandatory)
 - **Technical Backup slides** (optional)
 - **Reviewer-Only slides** (optional)
- **The following slides include:**

Instruction

Example Slide

(Guidance for constructing the specific slides and sections)

(Examples are from previous AMR posters)

- Include:
 - Project title
 - Name of the principal investigator
 - Name of the presenter if different from the principal investigator
 - Organization
 - Project ID# (which ORAU will provide to you)
 - Statement: “This presentation does not contain any proprietary, confidential, or otherwise restricted information.”

2023 DOE Vehicle Technologies Office Annual Merit Review Presentation

(replace with your title)

P. I. Name (always include)

Presenter Name (if not the P.I.)

Organization

Date

Project ID #

(this will be provided to you)

This presentation does not contain any proprietary, confidential, or otherwise restricted information

Title Slide Examples

Graphene-Enriched Hierarchical Polymer Additives Derived From Natural Gas

PI: George Skoptsov | H Quest Vanguard, Inc., Pittsburgh, PA | DE-SC0021767 | MAT255

PI: George Skoptsov
H Quest Vanguard, Inc.

Graphene-enriched hierarchical polymer additives derived from natural gas

June 22, 2022
DOE Vehicle Technologies Office Annual Merit Review (AMR)

Overview

Timeline and Budget

Project start date: 08/04/2021
Project end date: 06/23/2022

Total funding: \$206,500
Percent complete: 80%

Objective

Enable mass production of low-cost reinforced automotive composites or chopped recycled carbon fiber.

Innovations

• New process enabling rapid (< 5 sec) upgrading of chopped carbon fiber via separation, etching, and decoration in a single microwave plasma process.

• Demonstrated applicability to other solid carbon materials, e.g. upgrading of carbon black from tire recycling processes.

Impacts

• 10x increase in surface area translates into significant interfacial strength increase for the chopped recycled carbon fibers.

• Stronger low-cost compression-molded composite parts promise further advances in automotive lightweighting.

• Applicability to a broad range of carbon materials encourages circularity and waste reduction in the automotive industry.

Technical Approach

Key Idea: Rapidly process chopped recycled carbon fiber in a microwave plasma reactor to improve interfacial strength in low-cost thermoplastic composites.

Process: Thermochemical process first etches and roughens the fiber surface and then deposits high-surface area carbons hybridized with crumpled graphene sheets.

Impact: Targeted tensile strength improvements of 70%-100% would enable low-cost injection-molded composite parts to meet price-performance requirements of automotive industry.

- Individual CF filaments heat up in reactor to ~1000C creating hot/ionized zones.
- Activated surface gas chemically attacks resin and carbon surface.
- Activated plasma promotes hybrid carbon deposition and growth.

Microwave plasma: rapid thermochemical process

- Rapid volumetric heating
- Continuous, high-throughput processing
- Instant start-up/shut-down
- No process CO₂ emissions
- Flexibility in feedstocks and products
- Compact, low-capital deployment

Summary

The demonstrated approach can significantly improve mechanical properties of thermoplastic resins with use of a novel hierarchical, hybrid reinforcement fiber (rHF).

The multi-scale surface of a recycled carbon fibers (rCF) is decorated with a high structure, graphene-enriched carbon black (GCB) to dramatically improve the short fibers interfacial and inter-lamellar shear strength metrics in low-cost thermoplastic resins.

H Quest previously demonstrated standalone GCB as a novel carbon nano-additive, synthesized from gaseous hydrocarbon feedstocks (methane or higher alkanes) in a microwave plasma synthesis.

Unlike other carbon nano-additives such as nanotubes or graphene sheets, production of which requires use of catalysts and a slow surface vapor deposition process, GCB is formed rapidly (order of microseconds) and volumetrically in gas phase. This enables continuous, high-throughput, low-cost processing (\$0.25/kg before cost of equipment).

The compounded effects of hybridizing the chopped carbon fiber with GCB would significantly exceed those of sizings or nanoparticle additives.

The significant increase in ultimate tensile strength (targeted 70%-100%) of the rCF-reinforced thermoplastic parts without significant increase in cost is envisioned to enable adoption by the automotive industry, promote lightweighting, and improve circularity of carbon fiber materials.

Acellent

Integrated Self-Sufficient Structurally Integrated Multifunctional Sensors for Autonomous Vehicles

Acellent Technologies Inc.
PI & Presenter : Amrita Kumar, Ph.D. Project ID: mat212

Presented at
2022 DOE Vehicle Technologies Office Annual Merit Review (AMR), June 21, 2022

This presentation does not contain any proprietary, confidential, or otherwise restricted information.

Barriers and Technical Targets

The Department of Energy (DOE) Vehicle Group* has identified a need for novel multifunctional composite materials and structures for the automotive industry that have the capability to reduce weight and volume as well as costs of "conventional" structural components by performing engineering functions beyond load carrying.

*Autonomous Vehicle Technical Requirements and Design Signposts and System Architecture Studies Report, Version 3.0, 2019

Acellent is developing an integrated AUTO-SMART sensor system for the automotive industry that will address this need.

Partners

- Manufacture collaborations - Standard University, Ford Motor Company
- Project lead - Acellent Technologies Inc.

Technical Accomplishments & Progress

Phase II is focused on validating the PPS system

I. Production protection system (PPS)

System Usage Architecture and Algorithm development

Flexible, easy-to-install sensors

SMART sensors

- The, selective film with embedded pre-designed network of piezoelectric sensor structures
- Flexible and adaptable to any structure and geometry

Approach

Relevance

Impact: The multifunctional sensing system will provide numerous benefits to the automotive and electric vehicle industry including:

- Enhanced safety through real-time detection of impacts.
- CB-based production costs saving protection.
- Optimal advanced sensing that can reduce the cost of vehicle inspection and maintenance.

Practical applications include electric and autonomous vehicles, commercial vessels, infrastructure etc.

Objectives: The following developments were completed in this program with Phase II focusing on developing a complete design for the AUTO-SMART sensor system:

1. Determining the design for a production ready sensing system that has the capability to detect any impact event occurring on the front bumper of an automobile within a very short duration and generate the proper response signal to a built-in protection system. A prototype is being developed and tested on Phase II for the production protection system.
2. Developing a battery monitoring system (BMS) for EV cars. The innovative BMS will provide State-of-Charge (SOC) and State-of-Health (SOH) of a battery with high precision.

Technical Accomplishments and Progress

The focus in the project to date has been on the development of the Production Protection System (PPS) Phase II accomplishments to date include the following:

- Obtained EV vehicle bumper from Ford
- Identified sensor layout and location for sensor installation on the bumper
- Developed the requirements for the PPS system
- Developed a test setup for the PPS
- Manufactured sensors and installed on the bumper. Tests for data collection are currently ongoing.
- Developed impact detection DAQ prototype hardware for use with testing
- Developed algorithms for detection of impact events on the front bumper of an automobile in a very short duration of time. These are currently being tested.

Proposed future research

Future tasks (to be completed in Phase II)

In Phase II, the program proposes to comprehensively develop multifunctional systems for cars. The two systems - PPS and BMS/ battery monitoring, will be developed using a unified architecture for implementation of both multifunctionalities in a vehicle design.

Mandatory Overview Slide

- Please prepare an Overview slide formatted and containing the information per the following slide:
 - Timeline (please confirm dates with your DOE HQ/NETL manager(s))
 - Budget (please confirm values with your DOE HQ/NETL manager(s))
 - Barriers (please list up to three technical barriers and technical targets from the most recent U.S. DRIVE Roadmap addressed by your project to be found at: <https://www.energy.gov/eere/vehicles/us-drive-partnership-plan-roadmaps-and-accomplishments>. MAT presenters should use the Light-Duty Workshop Final Report at https://www1.eere.energy.gov/vehiclesandfuels/pdfs/wr_ldvehicles.pdf as their guide. If you don't see a report on your subject matter, please contact the relevant Technology Manager.
 - Partners

Timeline

- Project start date
- Project end date
- Percent complete

Budget

- Total project funding
 - DOE share
 - Contractor share
- Funding for FY 2022
- Funding for FY 2023 (if available)

Barriers and Technical Targets

- List up to three technical barriers and technical targets from the most recent U.S. DRIVE Roadmap relevant to your project. For a list of roadmaps by subprogram, please see the link below:
<https://www.energy.gov/eere/vehicles/us-drive-partnership-plan-roadmaps-and-accomplishments>
- If you don't see a report on your subject matter, please contact the relevant Technology Manager.

Partners

- Interactions/collaborations
- Project lead

Overview



Timeline

- Start date: Aug 23, 2021
- End date: Aug 22, 2023
- Project complete: 30%

Budget

- DOE SBIR FY2021: \$1.1M

Partners

- Subcontractor: University of North Texas
- Project Lead: Newport Sensors, Inc.

Barriers and Technical Targets

- High fiber cost and difficulty in damage inspection hinder wide deployment of lightweight CFRP composites for reducing vehicle GHG emission

(Light-Duty Vehicles Technical Requirements and Gaps for Lightweight and Propulsion Materials Workshop Report, February 2013)

Overview Slide Examples

OVERVIEW

Timeline

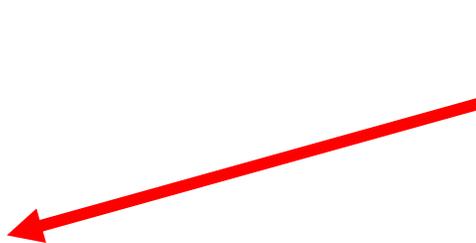
- Project start date: October 2018
- Project end date: September 2024
- Percent complete: 70%

Budget

- Total project funding: \$1,000,000
- U.S. Department of Energy (DOE) share: \$1,000,000
- Funding for FY 2021: \$250,000
- Funding for FY 2022: \$250,000

Barriers addressed

- Cost, power density, and lifetime.



NREL Electric Motor Thermal Management
 PI: Kevin Bennion (National Renewable Energy Laboratory); Team: Emily Cousineau, Doug DeVoto, Xuhui Feng, Bidzina Kekelia, Jeff Tomerlin (NREL); Mostak Mohammad (ORNL); Iver Anderson (Ames Laboratory); Todd Monson (SNL); Yogendra Joshi, Satish Kumar (Georgia Institute of Technology); Bulent Sariloglu, Thomas Jahns (University of Wisconsin-Madison)

June 21-23, 2022 – Project ID: ELT214

OVERVIEW

Timeline

- Project start date: October 2018
- Project end date: September 2024
- Percent complete: 70%

Budget

- Total project funding: \$1,000,000
- U.S. Department of Energy (DOE) share: \$1,000,000
- Funding for FY 2021: \$250,000
- Funding for FY 2022: \$250,000

Barriers addressed

- Cost, power density, and lifetime.

RELEVANCE

This project is part of the Electric Drive Technologies (EDT) Consortium and focuses on NREL's role under Keynote 2. The research enables compact, reliable, and efficient electric machines

- Motor 10x power density increase (2025 versus 2015 target) [1]
- Motor 2x increase in lifetime [1]
- Motor 53% cost reduction (2025 versus 2015 target) [1]

[1] U.S. DRIVE. 2017. *Electrical and Electronics Technical Team Roadmap*. <https://www.energy.gov/eere/vehicles/electrical-and-electronics-technical-team-roadmap>

ACKNOWLEDGMENTS

Susan Rogers, U.S. Department of Energy

For more information, contact:

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 Phone: 303-271-4902

NREL Principal Investigator
 Kevin Bennion
 kevin.bennion@nrel.gov
 Phone: 303-271-4447

APPROACH

Electric Drive Technologies Consortium Team Members

NREL-led Thermal Management Research

- Material and Interface Thermal and Mechanical Characterization
- Motor System Thermal Analysis Support

COLLABORATION AND COORDINATION

Material and Interface Thermal and Mechanical Characterization

- Collaboration with Sandia National Laboratories (ELT216) to support mechanical and thermal measurements of new motor materials.
- Collaboration with Ames Laboratory (ELT215, ELT234) to support thermal analysis of electric machines enabled by material innovations.

Motor System Thermal Analysis Support

- Collaboration with University of Wisconsin (ELT243), with NREL providing technical support, thermal data, and material information to support integrated cooling of motor and power electronics.
- Collaboration with Georgia Institute of Technology (ELT251), with NREL providing technical support, geometry data, thermal modeling data, and NREL laboratory access to students for evaluations of advanced cooling impacts.
- Collaboration with Oak Ridge National Laboratory to support motor thermal analysis and thermal design of advanced machine design led by ORNL (ELT212).
- Collaboration with Keystone 3 project areas at ORNL (ELT211) and NREL (ELT217).

FUTURE WORK

- In collaboration with ORNL, build prototype heat exchanger to verify expected cooling performance in relation to the non-heavy rare-earth, high-speed motor research effort led by ORNL.
- In support of SNL, prepare for mechanical property tests of additional SNL material samples.
- Support Georgia Institute of Technology in efforts to model motor thermal management concepts, conduct experiments, and publish motor thermal management research results.
- Continue meetings and discussions with University of Wisconsin-Madison to provide technical support, thermal data, and material information to support integrated cooling of motor and power electronics.

SUMMARY

Approach/Strategy

- Supports research enabling compact, reliable, low-cost, and efficient electric machines aligned with roadmap research areas [1].
- Collaborate with ORNL, Ames, and SNL to provide motor thermal analysis support, reliability evaluation, and material measurements on related motor research at national laboratories.
- Collaborate with university partners including Georgia Institute of Technology and University of Wisconsin-Madison to support university-led motor thermal management and development research efforts.

Technical Accomplishments

- NREL collaborating with SNL to support mechanical and thermal measurements of new motor materials.
- NREL providing thermal design support for electric machine design process led by ORNL.

Collaborations

- Oak Ridge National Laboratory (ORNL)
- Ames Laboratory
- Sandia National Laboratories (SNL)
- Georgia Institute of Technology
- University of Wisconsin-Madison

ACCOMPLISHMENTS AND PROGRESS

Collaboration with Sandia National Laboratories (ELT216)

- Completed measurements of new motor materials with multiple metering block materials for experimental setup showing no change in results within 95% percentile confidence interval.

Collaboration with Oak Ridge National Laboratory (ELT212)

- Thermal design shaver to meet 30-second peak power temperature requirement.

Steady-state temperatures at 6,667 RPM and 62.2 kW (left). Transient temperature response at peak power operating point from steady-state showing ability to operate over 30 seconds before reaching 150°C temperature limit (right).

Sample from SNL undergoing thermal measurement. Photo by Emily Cousineau, NREL (left). Comparison of different metering block materials showing consistency of measured thermal conductivity within shown 95% percentile confidence intervals at two evaluated temperatures (right).

- Relevance counts for 10% of your total project score.
- The title of these slides should make it clear that they are your project's **Relevance**.
- Information to include:
 - Describe the objective of your project and what you were to achieve over the past year in the work covered by your presentation.
 - Clearly show **how your project relates to the pertinent VTO subprogram area** and how it will achieve the goals of that area (refer to the subprogram Annual Progress Report goals linked on the next page).
 - Explain how your project will be relevant to
 - Reduction of energy costs
 - Increased energy security
 - Clean energy technology to move people and goods
 - Describe the impact of your project on addressing the barriers identified in the Overview slide and other specific targets and milestones.

Relevance (Continued)

VTO Subprogram Goals

LINKS TO 2021 SUBPROGRAM ANNUAL REPORTS

- [Advanced Engine and Fuel Technologies](#)
- [Analysis](#)
- [Batteries](#)
- [Electrification](#)
- [Energy Efficient Mobility Systems](#)
- [Materials](#)

Argonne NATIONAL LABORATORY

ELECTRODE PROTOTYPING ACTIVITIES IN ANL'S CELL ANALYSIS, MODELING AND PROTOTYPING (CAMP) FACILITY

Steve Trask, Andrew N. Jansen (PI)

Project ID: BAT030

Overview

Timeline

- Start: October 1, 2014
- Finish: September 30, 2023

Budget

- FY22 - \$800K
- 100% DOE-EERE-VTO
- Partners: MERF, GAG, APS, CNM, PTF, universities, and industries

Barriers

- Development of PHEV and EV batteries that meet or exceed DOE/USABC goals – safety, cost, effective, sustainable, and low cycle life.

Relevance

- Transition new high energy battery chemistries invented in research laboratories to industrial production through independent validation and analysis in prototype cell formats.
- xx3450 & xx6395 pouch cells; ranging from 20 to 3,000 mAh capacity.
- Researchers are often not able to provide the quantities of novel materials needed to make a full-size EV cell to demonstrate the merits of their discoveries. The CAMP facility is specifically designed to explore new materials with quantities as small as 50 grams for active materials, and even less for electrode/electrolyte additives.

Approach

- Researchers submit materials with promising energy density
- Small hand-coated electrodes are made
- Cost cells are made and tested
- Larger material samples are obtained (NMC, NCA, etc.)
- Larger lengths of electrodes are made from 100 pouch cells and tested
- Advanced diagnostic & chemical modeling process technologies

Progress

Multi-functional Coater

Demonstrated High Quality Coatings During Factory Acceptance Test

Uniform thin coatings using the spray coating head.

Verified functionality of:

- Interchangeable coating heads
- Roll drying system
- Corona treatment
- Progressive cavity pump

Progress

Multi-functional Coater Installed in Dry Room

Coating system greatly enhances adaptability for coating various materials.

Materials for Diversifying Supply Chains and Increasing Sustainability

LiNi_{0.8}Mn_{0.2}O₂ (MRF & RNGC)

- Produced high quality slurry dispersion using high pH LNO-based oxide powder by mitigating gelation using slow order of addition process and temperature control
- Evaluated in 1.5 Ah pouch cells

see BAT167, BAT251, BAT252, BAT253

LiMn_{1.5}Ni_{0.5}O₄ (commercial)

LifePO₄ (MERF) See BAT470

Full Cell Impedance Performance

90 wt% LFP (made by MERF)
5 wt% Tinsel C-45
5 wt% Solvay S130 PVDF Binder
Coating Thickness: 84 μm
Total Coating Loading: 18.88 mg/cm²
Total Coating Density: 2.01 g/cm³
Area Density: 2.81 g/m²
Made by CAMP Facility

~5V spinel electrodes with single wall carbon nanotubes (SWCNT) show lower cell impedance

see BAT252

~60% Mn, Co-free baseline powder for Earth-Abundant Cathode Active Materials (EaCAM)

see BAT251

~30 mAh pouch cells (LFP/Gr) assembled and testing still in progress

Summary

- Developed methods to coat electrode-ceramic structure coating with roll-to-roll reverse comma coating with loading targets ranging from 1 to 3 mAh/cm².
- Installed the multifunctional coater in the CAMP facility dry room.
- Studied X-ray methodologies to quantify electrode expansion in NMC811/Li cells.
- Provided advanced prototype electrodes in the Electrode Library by producing >100 meters of anodes and cathodes (baseline and novel materials) in support of various DOE battery programs.
- 1,807 sheets (FY21) 923 sheets (FY22 as of April 2022)
- Produced high quality electrodes using LNO 90Mn0.05Co0.05O2 powder by mitigating gelation and produced 1.5 Ah pouch cells.
- Produced electrodes using powders relevant to domestic supply chain and environmental sustainability, provided by RGC, (LMR-NM) and MERF (LFP).
- Supplied numerous experimental electrodes and cells to DOE programs.
- 247 cells (FY21) 146 cells (FY22 as of April 2022)

X-ray Methodologies to Quantify Electrode Expansion

Developed X-ray methodologies to quantify electrode expansion in NMC811/Li cells

- During charge Li⁺ ions are deposited on the Li, which expands and pushes the NMC811 cathode against the spring.
- During discharge, Li⁺ ions are stripped from Li, releasing pressure on the spring.
- NMC811 and PE edges move together indicating that the separator is not compressed. The movement is solely because of expansion and contraction of the Li metal.

Acknowledgment:

Relevance Slide Examples

Relevance

Data from S. Ahmed et al., J. of Power Sources 403, 56 (2018)

BEV 60 kWh, 300 kW
ASI = 12 Ω·cm² @ 20% SOC
~4.4V vs. Graphite UCV

Relevance

- Cost and safety are still the main drivers in the development of EV batteries, Mn-rich oxides offer advantages in both
- Technoeconomic modeling (above, left) shows that Mn-rich electrodes have the potential to reach cost parity with state-of-the-art NMC-811 in terms of pack-level cost
- Work from this project (above, right) has demonstrated that Mn-rich electrodes can achieve similar performance to their NMC counterparts
- Importantly, Mn-rich compositions can be made with little to no cobalt while maintaining performance

Relevance

- Transition new high energy battery chemistries invented in research laboratories to industrial production through independent validation and analysis in prototype cell formats.
- xx3450 & xx6395 pouch cells; ranging from 20 to 3,000 mAh capacity.

4 mAh Coin Cells → x100 → 400 mAh CAMP Zone → x100 → 40 Ah PHEV/EV

- Researchers are often not able to provide the quantities of novel materials needed to make a full-size EV cell to demonstrate the merits of their discoveries. The CAMP Facility is specifically designed to explore new materials with quantities as small as 50 grams for active materials, and even less for electrode/electrolyte additives.

Milestones

Instruction

- Milestones may be presented in a separate slide directly before the Approach section or included as part of the Approach section.
- Include milestones and go/no-go decision points for FY 2023 and FY 2024.

Approach

- Approach counts for 20% of your total project score.
- The title of your slides should make it clear that they are your project's **Approach**.
- Describe overall Technical Approach:
 - Emphasize unique aspects of your work and de-emphasize discussion of equipment used.
 - Discuss how your work addresses the project's technical barriers.
 - Describe how your project is integrated with other research or deployment projects within the pertinent VTO subprogram.
 - Use simple statements so that scientists and engineers, not experts in your area, can readily understand the explanation of your approach.
- Include the planned milestones and go/no-go decision points for FY 2023 and FY 2024 and current status towards them (if not shown in a separate Milestone slide).

Approach Slide Examples

LOW-COST RESIN TECHNOLOGY FOR THE RAPID MANUFACTURE OF HIGH-PERFORMANCE FIBER REINFORCED COMPOSITES

Henry A. Sosa, PhD, President
Trimer Technologies, LLC
Project ID: mat216

PROJECT OVERVIEW

Barriers and Technical Targets

- Lack of cost-effective systems and designs, including heating and high-volume processing
- Joining technologies for carbon fiber composites to each other or within a multi-layer system are inadequate
- The ability to form the fiber to the resin is inadequate to take full advantage of the inherent properties of the fiber. USDOE's Materials Technical Team Workshop October 2017, section 9

Partners

- Project Lead: Trimer Technologies, LLC
- Project Evaluator: WACM-SUP
- Project Co-Leader: TPI Composites
- Funder: TPI

Budget

Total Project Funding \$1,150,000

TECHNICAL PROGRESS

Resin Transfer Molding

- RTM process developed for high pressure with a closed mold which is heated to cure the resin
- Resin injected at pressure around 100 Bar (~1,500 PSI)
- Viscosity reduction allows for fast and full infiltration of the resin, known as flow sweep. It has high impact on cycle time and part quality
- Highly porous resin allows for low cycle time and high part quality
- Good for complex and high-performance parts with continuous fibers
- Performance can greatly exceed cast molding (DOW) (DOE)

TECHNICAL PROGRESS

Environmental Testing

- Trimer resin and beam samples prepared by VAMTA that were heated to 70° C and irradiated at 100% humidity at 70° C for 30 hours
- There was a slight decrease in the performance under these conditions
- Short beam samples were also coated in 70° C and likewise showed a slight reduction in performance
- Current data shows that there is statistically significant impact on resin properties
- These results suggest the fatigue performance of Trimer composites would not drop significantly under these conditions
- Room temperature fatigue testing has been completed with OEM partners and has shown similar or improved performance when compared to epoxy
- Further environmental testing will be performed throughout the program

OPPORTUNITY

- Carbon fiber composites provide 30-70% weight savings over steel
- New materials with both rigid and adequate impact mechanical properties are required
- Trimer resin allows for 4 minute cycle times
- Trimer has achieved the DOE's 2000 goal for cycle time under 1 min

APPROACH

Trimer's Thermoset Resin

- Low viscosity for rapid infusion
- Rapid Cure - as fast as 30 sec at 140°C
- High strength, stiffness and toughness
- Non-flammable
- High glass transition temperature
- Low-cost high-performance

FUTURE RESEARCH

- Trimer has demonstrated the capability to achieve molded continuous fiber composites in under 60 seconds, a critical manufacturing goal
- Commercialization of Trimer's resin requires extensive process development and related testing necessitating further work
- Trimer will perform HP-RTM manufacturing at WACM-SUP in the next couple of months
- Resin adoption in high volume automotive manufacturing requires scale up of the manufacturing process and to focus on current customer
- Component level testing will be required for the commercialization of Trimer's resin in production automotive components. Benefits requiring close partnership with OEMs

SUMMARY

- Carbon fiber composites provide 30-70% weight savings over steel providing a critical performance advantage
- Trimer Technologies has developed a revolutionary low viscosity thermosetting resin which can enable fast cure and achieve excellent mechanical properties
- Mechanical properties greatly exceed state of the art automotive resins
- Polymer exhibits very high glass transition temperature (up to 200° C) which can enable fast cure in white electronics
- Trimer resin can be used in cycle 45 sec
- Cycle time exceeds the DOE's 2000 goal for cycle time under 1 min
- We have developed core technology to reduce the reaction time allowing extended molding times for larger structures
- Testing has shown the resin to be non-flammable and offers F27 performance exceeding the current state of the automotive industry

APPROACH

Wound Field Synchronous Machines (WFSMs)

- Wound field synchronous machines have several attractive features for use as electric vehicle traction motors
- No permanent magnets
- Easy field weakening, reduced iron losses at high speed and high power factor through field excitation control
- High power factor may allow the inverter kVA rating to be reduced

Brushless Capacitive Power Transfer (CPT)

- Brushless capacitive power transfer uses two sets of rotating capacitors or electrodes in which an AC electric field is established by a high frequency inverter.
- A displacement current can flow through the airgap in the rotating capacitors which is rectified on the rotor using a diode bridge.

Multiple Generations of WFSMs and CPT Systems

- Three generations of WFSMs and three type of capacitive power coupler (CPC) systems were developed
- Increasing power density WFSMs with each generation
- CPT systems developed include journal bearings, printed circuit board (PCB) based integrated magnetic and capacitive transfer, and large gap PCB in single and three phase variants

APPROACH

Trimer's Thermoset Resin

- Low viscosity for rapid infusion
- Rapid Cure - as fast as 30 sec at 140°C
- High strength, stiffness and toughness
- Non-flammable
- High glass transition temperature
- Low-cost high-performance

Material Property	Trimer Technologies' RTM Resin	Dow Veroform 5300	Huntsman Araldite LY 3585 / Aradur 3475	AOC VIPOL F010 B1S-A VE	Reichhold DION IMPACT 9102-73
Polymer Type/Chemistry	Epoxy	Epoxy	Epoxy	Vinyl Ester	Vinyl Ester
Glass Transition, Tg Dry °C	373	120	110	130	99
Tensile Strength (MPa)	103	68	77.5	88	79.2
Tensile Modulus (GPa)	4.0	2.8	3.8	3.2	2.9
Tensile Strain to Failure, %	4.0	7	9	6.2	4.5
Compressive Strength (MPa)	149	-	-	121	108.9
Flexural Strength (MPa)	140	-	-	153	144
Fracture Toughness, K1c (MPa·m ^{1/2})	1.03	1.22	0.85	0.6	-
Viscosity (cP at 23 °C)	200	500	1,000	1,200	170

Wound Field and Hybrid Synchronous Machines for Electric Vehicle Traction with Brushless Capacitive Rotor Field Excitation

PI: Ian Brown (Illinois Institute of Technology)

OVERVIEW

Timeline

- Project start date: October 2017
- Project end date: September 2021
- Percent complete: 100%

Budget

- Total project funding: \$1,112,707
- U.S. Department of Energy (DOE) share: \$999,752

Barriers addressed

- The cost of electric vehicle traction motors has been resistant to reduction
- The rare earth permanent magnet market is subject to significant price and supply volatility
- The power factor of interior permanent magnet synchronous machines (IPMSMs) and induction machines (IMs) increase the kVA rating and cost of traction inverters

RELEVANCE

- This project developed cost effective wound field synchronous machines (WFSMs) and hybrid excitation machines (HEMAs) which meet DOE USDRIVE performance and cost metrics
- Removal of permanent magnets in the rotor through the development of cost effective and robust capacitive power couplers for brushless rotor field excitation power transfer

COLLABORATIONS

- University of Wisconsin-Madison (Prof. Dan Lubbo)

FUTURE WORK

- This project has finished though many of the technologies initiated in this project continue to be developed in DE-EE000866

ACKNOWLEDGEMENTS & CONTACTS

Steven Boyd, U.S. Department of Energy

For more information, contact:
IT Principal Investigator
Prof. Ian Brown
Phone: 618-552-8000

APPROACH

Wound Field Synchronous Machines (WFSMs)

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- No permanent magnets
- Easy field weakening, reduced iron losses at high speed and high power factor through field excitation control
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Brushless Capacitive Power Transfer (CPT)

- Brushless capacitive power transfer uses two sets of rotating capacitors or electrodes in which an AC electric field is established by a high frequency inverter.
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Multiple Generations of WFSMs and CPT Systems

- Three generations of WFSMs and three type of capacitive power coupler (CPC) systems were developed
- Increasing power density WFSMs with each generation
- CPT systems developed include journal bearings, printed circuit board (PCB) based integrated magnetic and capacitive transfer, and large gap PCB in single and three phase variants

ACCOMPLISHMENTS AND PROGRESS THIS BUDGET PERIOD

Construction of Generation III WFSM

- The efficacy and power density of WFSMs is too a great extent determined by the stator and field slot fills as they are ohmic loss dominated
- Three different high slot fill field windings were designed using square conductors, twisted square conductors, and die compressed round magnet wires
- A hairpin winding stator from a Chevy Volt was used as it is difficult and expensive to prototype a hairpin winding
- The square conductor and twisted square conductor rotors were prototyped

Dynamometer Testing of Generation III Wound Field Synchronous Machine with Brushes and Slip Rings

- The WFSM with a hairpin stator and square conductor rotor was dynamometer tested at the University of Wisconsin
- The ultimate limit to the testing of the power capability of the WFSM prototype is the stator inverter which has a maximum rated current of ~230 A_{ms}. The peak current of the WFSM stator is ~427 A_{ms}.
- Only partial load points could be tested for comparison with finite element predictions. The results are very close

Dynamometer Testing of Generation III Wound Field Synchronous Machine with Single Phase Large Gap PCB Capacitive Power Coupler

- The same WFSM that was tested with brushes and slip rings was also tested with a single phase large gap PCB CPC and two generations of high frequency GaN inverters
- Construction of the generation III WFSM with hairpin stator and two high slot fill field winding variants: square conductor and twisted square conductor
- Development of a journal bearing capacitive power transfer system
- Development of an integrated magnetic and capacitive power transfer system based on printed circuit boards
- Development of large gap printed circuit board capacitive power transfer system in single and three phase variants
- Development of kilowatt level, megahertz switching frequency, single and three phase high frequency Gallium Nitride inverters for excitation in the capacitive power transfer systems
- Current measurement and phase lock loop control systems for the capacitive power transfer system
- A rating buck converter with a fixed duty cycle was created for impedance transformation to match the field winding to the high frequency inverter
- A new approach to the design of WFSMs using multi-material, magneto-structural topology optimization
- Parallel flux hybrid excitation machine

TABLE 2: PREDICTED AND MEASURED PERFORMANCE AT LOAD POINT 3 (2000 RPM)

	Torque (Nm)	IPhas (Amps)	IF (Amps)	Power Factor (%)	EFF (%)
FEA Predicted	119.66	134.33	3.66	0.95	93.83
Experimentally Measured	118.06	137.19	5.92	0.93	93.82

TABLE 3: PREDICTED PEAK VOLUMETRIC POWER DENSITIES

	4000 RPM Base Speed	6000 RPM Base Speed
Active Material Volume	37.7 kVA/l	57.6 kVA/l
Volume Including End Turns	24.0 kVA/l	36 kVA/l

TABLE 1: PREDICTED PERFORMANCE WITH SQUARE CONDUCTOR ROTOR

Load Point (RPM)	Speed (RPM)	Torque (Nm)	IPhas (Amps)	IF (Amps)	Power Factor (%)	EFF (%)
1	4000	133.05	6.83	8.26	7.62	93.26
2	8000	65.38	3.08	3.85	3.02	93.59
3	2000	119.68	6.72	7.65	7.10	93.85
4	4000	154.34	8.53	10.43	8.18	93.92
5	12000	151.37	6.83	18.60	7.20	93.99

Output power: 77.5 kW
Speed: 4000 RPM
I_q = 22.03 A_{ms}
I_d = 6.368 A_{ms}
V_{dc} = 400 V
EFF = 94.40%

Technical Accomplishments and Progress

- Technical Accomplishments and Progress count for 40% of your total project score.
- The title of these slides should make it clear that they are your project's **Technical Accomplishments and Progress**.
- Each slide should include a summary “take-home” message, especially those that contain data.
- **Describe the most important technical accomplishments achieved during the reporting period and their significance.** Specifically, address last year’s reviewer comments regarding technical accomplishments and progress as well as progress to date for new projects.
- Include relevant data to support your accomplishments.
- Relate the accomplishments to project milestones, barriers, objectives, and technical targets.
- Benchmark the progress versus FY 2022 results, if applicable.

Technical Accomplishments and Progress (Continued)

Instruction

- Include no more than one slide on previous accomplishments and CLEARLY indicate work previously presented versus new work.
- To assist the reviewers evaluating your work, please include bullet comments of the key points on each slide.
- Include sufficient slides to explain what was done leading to the technical accomplishments.
- Though your presentation will be in color, it is best to choose colors and data symbols that can be easily distinguished in black and white for those reviewers using hardcopies.

RELEVANCE

- Complete aqueous electrode digestion properties and thick electrode coatings to cell performance to reduce cell cost.
- Demonstrate an energy density to >300 Wh/kg (cell level) for solid state batteries.

OBJECTIVES

Major Objectives:

- Improve cell energy and power density and reduce battery pack cost by tailored electrode architecture via aqueous processing and utilizing high energy high voltage cathode materials.
- Fabricate thick and crack-free composite cathodes via aqueous processing.
- Facilitate compatibility of high rate solid state aqueous processing.
- Develop bilayer graphite anodes via freeze tape casting for improved rate performance.
- Develop polymer electrolyte for solid state batteries.
- Understand the conduction mechanism in polymer electrolyte and optimize the formulation.
- Demonstrate a solid state battery with an energy density >300 Wh/kg (cell level).

PROGRESS MILESTONES

Date	Event	Progress
5/15/2017	Discovery	Demonstrated high energy and power density from layered electrodes and freeze tape cast, achieving >10% improvement at high rate performance (Pysys)
6/15/2017	Annual Checkin	Fabrication composite cathodes for solid state batteries and demonstrate an energy density > 300 Wh/kg at cell level and > 20 cycles

TECHNICAL APPROACH

- Electrode coating on thick electrodes.
- Mass transport limitations thick electrodes.

Technical approach and strategy:

- Apply bilayer NMC622 electrodes with high areal loading in a slurry for aqueous processing.
- Develop bilayer electrode architecture via freeze tape casting.
- Develop composite polymer electrolyte.
- Characterize the electrochemical performance of the composite electrodes.
- Track the electrochemical interface.
- Evaluate rate performance and long term cyclability.

COLLABORATION

Partners:

- ORNL-LIFE, Argonne National Laboratory, Sandia National Laboratory
- Battery Manufacturing, Mercedes System
- Advanced Manufacturing, Progress Superior Graphite, Ingersoll Rand
- Facility Material Sciences, ORNL, Solvay Specialty Polymers, Voltalia, Vestris
- Equipment/Chemical Supplies, PPS Innovation, Invencon Industrial Technology, NMC MEDICAL, ChemPlyco
- Independent, MIT, Empowerment University, University of Florida John Verna

TECHNICAL ACCOMPLISHMENTS

Executive Summary:

- Demonstrated crack- and defect-free flexible graphite and NMC622 cathodes by freeze tape casting (FTC)
- Tailored the aqueous slurry formulations to control the structure of the cathode
- Demonstrated 20% improvement in capacity under 5C and 10 min charging from graphite anodes
- Delineated the Li⁺ ion conductivity mechanism in hybrid solid state electrolytes based on Al-LiZO
- Correlated the conductivity mechanism with the microscopic electrochemical performance
- Investigated the electrochemical stability of LITFSI vs LFSI
- Designed principles to synthesize electrolytes with tailored properties

Developed bilayer graphite anode via FTC and demonstrated ~20% improvement in capacity

The bilayer graphite anode demonstrated excellent mechanical integrity, shorter diffusion length, ~20% improvement in capacity under 5C charging and 10 min total charging time, and improved cycle life.

Demonstrated crack-free and thick NMC622 cathodes (4.7 mAh/cm²) via FTC

- Vertical channels were formed in the NMC622 cathode
- Large void space in the channels
- Denser and more durable structured cathodes enabled by tailoring the water content of the slurry formulation

Composite electrolytes based on poly(ethylene oxide) filled with Al-doped Li_{1-x}La_xZr₂O₁₂ platelets

Cubic phase Al-LiZO platelets

- Better against dendrite formation
- Good adsorption of the polymer electrolyte

Optimize formulation and processing conditions

- Li salts: LITFSI, LFSI
- PEO, LITFSI, LFSI dissolved in acetonitrile (ACN) or other solvents

TECHNICAL ACCOMPLISHMENTS

Executive Summary:

- Demonstrated 20% improvement in fast charge stability in bilayer graphite anode via FTC
- The porous Al-LiZO films resulted in substantial improvement of the charging rate performance
- The addition of Al-LiZO film significantly increased conductivity with faster dynamics
- FTC cast showed higher conductivity than LTPS in composite electrode
- The Al-LiZO films significantly change the conductivity mechanism: The Li⁺ ion dynamics become faster and the conductivity increases. Possible interfacial conductivity mechanism
- The rate of the dynamic strength (number density of the ions) contributing to the mechanism is associated with the electrode conductivity

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Accomplishment Slide Examples

Technical Accomplishments

Understanding Low SOC Impedance

- Green region** – standard, high-voltage, layered type sites – mostly unaffected by voltage fade retaining fast Li ion transport throughout cycling
- Yellow region** – very narrow voltage/SOC range where ASI becomes substantial as high-voltage sites are filled, leaving mostly low voltage/disordered sites ('layered component' has slow kinetics as it nears full lithiation)
- Red region** – At higher rates, Li insertion into these sites becomes very limited

The activated electrode may be thought of as a percolating network of high-voltage sites with fast Li-ion diffusion – throughout this network are local regions of disordered, low-voltage sites with poor Li diffusion properties

In addition to local phenomena, primary/secondary morphology influence impedance – synthesis is critical

Responses to Previous Year Reviewers' Comments

- All VTO AMR reports are posted on the VTO website along with Annual Progress Reports at <https://www.energy.gov/eere/vehicles/annual-progress-reports>.
- Last year's presentations can be found at: <https://www.energy.gov/eere/vehicles/annual-merit-review-presentations>.
- **If your project was not reviewed last year, please indicate as such on the slide.**

Reviewer Comment Slide Examples

DISTRIBUTIONS OF REAL-WORLD VEHICLE TRAVEL Project ID: VAN036
VTO Annual Merit Review, June 22, 2022

David Clarke - Argonne National Laboratory

PROJECT OVERVIEW
Objective: Improve information needed to compare economics of vehicle operation across multiple vehicle technologies in a balanced manner, accounting for variation in travel and ownership behavior.

RELEVANCE
• Driving behavior is not homogeneous, and using a single mileage schedule for all calculations related to lifecycle emissions, cost of ownership, and vehicle survivability does not yield a full understanding of real-world fuel consumption.
• Vehicle choice models used for analysis and for policymaking rely on assumptions about vehicle miles traveled (VMT) and vehicle lifetime.
• Optimal vehicle choices from a limited cost of driving distribution may vary depending on operating use cases.
• New technologies are more likely to be useful to a subset of consumers before the vehicle market, e.g., a battery electric vehicle driver more intensively than the average may have an easier time reaching zero parity than a "typical" operator.

APPROACH
• Quantify variability in vehicle miles traveled (VMT), considering mileage, vehicle characteristics, and demographic characteristics.
• Quantify lifecycle cost of driving (LCOD) for vehicles with different use scenarios.
• Estimate how variability in VMT impacts relevant cycle metrics such as fuel consumption and emissions, both for today's vehicles and potential future scenarios.
• Assess variability in vehicle survivability to determine typical length of time that different types of vehicles stay on the road.

PARTNERSHIPS AND COLLABORATIONS
• This project informed VTO's Total Cost of Ownership research project (FY2020, VAN035), and links into ANL's VTO24 modeling (VAN023). High-fidelity vehicle operating cost modeling is from an ongoing project funded by EERE's Strategic Analysis program.
• Vehicle registration data support from Equinox Automotive.
• Heavy-duty truck vehicle operational data gathered from California Department of Transportation through California Vehicle Inventory and Use Survey (California Truck Survey (CAVUS)).

TECHNICAL ACCOMPLISHMENTS: VMT DISTRIBUTIONS AND TCO
• Clean VMT distributions (shown below, analyzed in earlier years of this project), able to quantify variability in total cost of ownership (TCO) for different vehicle categories.
• Graphs to right show TCO for conventional internal combustion engine (ICE) SUV, hybrid electric vehicle (HEV), and battery electric vehicle (BEV), based on vehicles used in 2018.
• Columns and rows are 15-, 50-, and 80% percentiles for VMT for a typical small SUV, and a 3-year, 7-year, and 15-year (ownership) lifetime.
• BEV always lower cost than ICEV. BEV cheapest for most drivers at 15 years (shaded in green), cheaper than ICEV within 3 years for intense drivers (shaded in light gray).

TECHNICAL ACCOMPLISHMENTS: VEHICLE SURVIVABILITY
• Comparing vehicle registrations with initial vehicle sales, we can estimate survivability of vehicles dating back to the 1970s.
• We assume a logistic curve, following seminal work by Green and others.

TECHNICAL ACCOMPLISHMENTS: GEOGRAPHICAL VEHICLE DIFFUSION
• Average age of vehicles varies across U.S.
• Lowest ages in Northeast, highest in Midwest.
• Lower vehicle ages near urban centers.
• Considering vehicles at the zip code level, we look at the distribution of vehicle ages.
• In the heat map to the left, zip codes are sorted by average high-income zip codes (on the top) and vehicle registrations are disaggregated by vehicle age on the horizontal axis (lower vehicles on left). Higher income zip codes tend to have higher number of total vehicle registrations per household.
• Higher income zip codes tend to have newer vehicles, and older vehicles diffuse through to lower-income locations (top left to bottom right).
• Electric vehicles are particularly prevalent in high-income zip codes. We consider other correlations that use income. Pickup trucks are a disproportionately used vehicle, especially for older models. Looking at submarkets, we find a clear increase in vehicle registrations in proximity to OEM manufacturing plants.

RESPONSES TO REVIEWER FEEDBACK
• Reviewers noted the potential lack of data for MHDV. Data has been acquired from CalTrans for use in future research projects.
• Reviewers noted potential difficulties in finding operational and ownership data for LDV. For VMT data, this continues to be difficult, but ANL has since acquired detailed registration data to better understand vehicle age distributions at a finer geographic level.
• Reviewers noted clear connections of this research with other VTO-sponsored research, but requested deeper connections with specific researchers across the laboratory system to help strengthen the research.
• Reviewers noted the interest in broader publications. Results were intended to be shared at TRB Annual Meeting in January 2022, but paper was withdrawn due to travel restrictions. Publication and dissemination of results continues to be a high priority.

SUMMARY & NEXT STEPS
• Vehicles are not used homogeneously, so it is important to account for variability.
• Differences by vehicle type, geography, fuel economy, ownership.
• Increased vehicle travel can make alternative fuel vehicles with lower operating costs but high purchase costs more cost-effective, which can have a negative impact for reducing fuel consumption or emissions.
• Substantive research has been reviewed (journals and conferences, including the Transportation Research Board Annual Meeting (Administration July for January presentation)).
• Vehicle mileage.
• Vehicle diffusion analysis.
• Work on developing a model vehicle choice cost is the next to a dynamic survivability function. The goal is to link reduced survivability as the vehicle ages with increases in operating costs (preventive maintenance and repair) to project usage of vehicles.

MILESTONES SINCE LAST ANNUAL MERIT REVIEW

Month/Year	Description	Status
June 2021	Report for TRB Annual Meeting: Distributions of VMT by Disaggregated and Vehicle Characteristics	Complete
June 2021	Presentation comparing levelized cost of driving for different use segments	Complete
Sept 2021	Documentation report on analysis of scrapage rates as a function of vehicle characteristics	Complete
Dec 2021	Identification of data sources for nationwide daily vehicle usage distributions	Complete
Mar 2022	Geographical linkage of vehicle registration throughout vehicle lifetimes, incorporating equity data and used vehicles	Complete
Jun 2022	Development of integrated TCO/ownership model	On track
Sept 2022	Cost parity and usage analysis for different powertrains and vehicle use cases	On track

This presentation does not contain any proprietary, confidential, or otherwise restricted information. Any proposed future work is subject to change based on funding levels.

Argonne National Laboratory

RESPONSES TO REVIEWER FEEDBACK

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Responses to Previous Year Reviewers' Comments

NEUPORT sensors

"The impact or other damage sensing needs to be demonstrated using an automotive CFRP to be relevant or, alternatively, the sensing technology could be pursued as a coating or thin layer to be applied to automotive composites to track impact. In that case, it does not need to be composed of CF itself, as CF on the vehicle is for mechanical reinforcement, not for use as electrodes."

- We modified our approach for PVDF film to be applied on the CFRP surface for easier integration into automotive parts
- We still use the CF as the electrode for the purpose of signal ground which should not have any obstacle

"It was not clear to the reviewer if the sensing is a damage detection or an impact detection. The reviewer asked about how the signals differ between an impact without causing damage and an impact with damage. Also, it is not clear if the capacitor circuit and the high pass filter circuit are embedded in the composite structure or they are separate from the composite."

- The piezoelectric sensor can detect initiation of microcracks of the composites.
- We added conductive trace sensor for strain measurement and surface crack detection which further enhances the damage detection functionality.
- All circuits will be separated from the composite

8

Responses to Previous Year Reviewers' Comments

This program was not reviewed last year

Collaboration and Coordination with Other Institutions

Instruction

- Collaborations and Coordination with Other Institutions count for 10% of your total project score.
- The title of these slides should make it clear that they are your Collaborations and Coordination with Other Institutions.
- List your project collaborators, indicating:
 - Relationship (for example, prime, sub, etc.)
 - Industry, university, National Laboratory
 - Within or outside VTO
 - Extent of the collaboration
- Describe the quality of collaborative relationships and their importance in achieving the project's objectives.

Collaboration Slide Examples

Collaboration



University of North Texas (Sub)
(Prof. Sheldon Shi)

- Hemp/Epoxy Composite Panel Fabrication
- Tensile Test: ASTM D3039
- Bending Test: ASTM D7264
- Impact Test: ASTM D6110



Hemp Fiber Mat



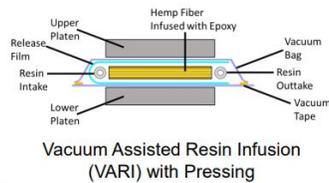
Wabash Genesis Hydraulic Hot Press



Shimadzu AGSX



AMETEK Impact Testing Machine



Vacuum Assisted Resin Infusion (VARI) with Pressing

Collaboration and Coordination with Other Institutions

Collaborators (Phase II)

• Stanford University (Phase II)

Under an ARPA-E funded project, Stanford is developing "Multifunctional Energy-Storage Composites (MESOC)" for the energy efficient design of light-weight electric vehicles. The focus of the ARPA-E program is on development for aircraft platforms. Stanford is collaborating with Acellent to develop and test the BMS system for automobiles.

• Ford Motor Company (Phase II and beyond)

Ford will work with Acellent in Phase II to provide bumpers, test car, coupon testing in selected environmental conditions specific to cars and guidance during the project.

Acellent Technologies Inc.
PI & Presenter: Anuraj Kumar, Ph.D. Project ID: smt212

Presented at
2022 DOE Vehicle Technologies Office Annual Merit Review (AMR), June 21, 2022

DOE presentation does not constitute any government endorsement or approval of the technology described herein.

Integrated Self-Sufficient Structurally Integrated Multifunctional Sensors for Autonomous Vehicles

Technical Accomplishments & Progress

System Usage Architecture and Algorithm development

Relevance

Approach

Collaboration and Coordination with Other Institutions

Technical Accomplishments & Progress

System Usage Architecture and Algorithm development

Relevance

Approach

Collaboration and Coordination with Other Institutions

BMS system

BMS system

Proposed future research

Summary

Collaboration and Coordination with Other Institutions

Collaborators (Phase II)

- **Stanford University (Phase II)**
Under an ARPA-E funded project, Stanford is developing "Multifunctional Energy-Storage Composites (MESOC)" for the energy efficient design of light-weight electric vehicles. The focus of the ARPA-E program is on development for aircraft platforms. Stanford is collaborating with Acellent to develop and test the BMS system for automobiles.
- **Ford Motor Company (Phase II and beyond)**
Ford will work with Acellent in Phase II to provide bumpers, test car, coupon testing in selected environmental conditions specific to cars and guidance during the project.

Remaining Challenges and Barriers

- Highlight the key remaining challenges and barriers to meeting the project objectives.
- The remaining challenges and barriers should provide justification and support for the future plans in the following slide.

OVERVIEW

Timeline

- Start - Oct. 1st, 2024
- Finish - Sep. 30th, 2025

Budget

- ↳ Total project funding is FY2022 - \$408K (in part of CAMP effort)
- ↳ 300K DOE

Barriers

- Development of sustainable EV batteries that meet or exceed DOE/USABC goals
- Cost
- Performance
- High energy active material identification and evaluation

Partners and Collaborators

- Development of sustainable EV batteries that meet or exceed DOE/USABC goals
- Cost
- Performance
- High energy active material identification and evaluation

RELEVANCE

- An overwhelming number of materials are being marketed/promoted to improve LIBs and batteries, which need to be validated for their impact on EV applications.
- CAMP Facility was established at Argonne to provide a realistic and consistent evaluation of candidate materials. Cell materials need to be validated internally to determine if they warrant further consideration.
- The benchmarking (validation) activities can also provide an objective opinion to material developers. Moreover, the better understanding of the active materials at cell level will speed up material development efforts.

FY22 MILESTONES AND ACCOMPLISHMENTS

Accomplishments

- Various solid electrolyte were prepared by different methods
- Electrochemical performance was evaluated at various temperatures
- Thermal stability was evaluated using DSC and TGA
- Characterization of materials was performed using XRD, SEM, TEM, EDS, etc.
- Electrochemical performance characterization of sulfur carbon material from Zeta Energy
- Carbon Nano Structure materials from Cabot as conductive additive for silicon anode battery

APPROACH AND STRATEGY

- Collaborate with material developers and leverage Argonne's expertise in electrode design and cell testing
- Cell materials that have an impact on the cell performance will be considered for testing using in terms of
 - Electrochemical performance
 - Thermal stability
- Electrochemical performance will be validated using 2032 coin type cells under test protocol defined from USABC EV requirements

OBJECTIVES

- To identify and evaluate sustainable low-cost cell chemistries that can simultaneously meet the following criteria for EV applications:
 - Electrochemical performance
 - Abuse tolerance
 - Cost
- To enhance the understanding of advanced cell components on the electrochemical performance and safety of LIB.
- To support the CAMP Facility for prototyping cells and electrode library development.

SOLID POLYMER ELECTROLYTE (SPE) PREPARATION AND CHARACTERIZATION

ELECTROCHEMICAL STUDY OF SULFUR-CARBON (SC) MATERIAL FROM ZETA ENERGY

FY21 - FY22 COLLABORATIONS

- The partners and collaborators include:
 - National Lab: Argonne, INEL, INEL, UREL, ORNL, SLAC, ORNL, IPNL, UIUC/UCR, Berkeley, Virginia University, LUTP, Northumbria University, University of Arkansas, University of Colorado, University of Missouri, University of North Carolina at Charlotte, Western Michigan University
 - Industry: Applied Materials, East Carbon and Black Stone, Corby, Conserve, All Energy Storage Technologies, Housa, Mithras, Osaka Titanium Corp., USABC, Panasonic Energy, Philips 66, Superior Graphite Co., Targray, Tada Kagaku, Zeta Energy
- The CAMP Facility is open to work with industries to advance the LIB technologies for EV application.

REMAINING CHALLENGES AND BARRIERS

- High energy active material identification and acquisition remain a challenge.
 - Existing commercial active materials can't meet or exceed DOE/USABC goals.
 - Getting access to advanced active materials is not always successful.
- As a benchmarking activity, the focus of this work is to validate the performance of cell materials (including electrochemical and thermal properties).
 - Research efforts between the validation and research needs to be balanced.

FUTURE RESEARCH

- We will continue the research on solid state electrolyte (SSE), focusing on its conductivity, stable cycling, and fabrication capability. Prototype cells using the studied oxide and sulfur SSE (LLZO, LIPSCl) will be fabricated and tested.
- We will continue to acquire and characterize high energy anode/cathode materials from researchers including new binders, electrolytes/additives, and alternative conductive materials, etc. if needed.
- Thermal properties of high energy anode/cathode materials will be investigated.
- Continue to work closely with research institutions and industrial suppliers to enable the LIB technology for EV applications.

SUMMARY

- We investigated solid state electrolytes from various aspects:
 - Preparation of polymer electrolyte was successfully prepared using thermal curing process. Good electrochemical performance was obtained using LIPSCl.
 - Sulfur carbon (SC) material from Zeta Energy was fabricated and tested with good performance.
 - Carbon Nano Structure materials from Cabot as conductive additive for silicon anode battery were investigated.
- An electrochemical-mechanical model was developed to investigate the an anode formation and propagation in solid-state electrolyte.
- Material from Zeta Energy was tested in LISC cell and good cycle performance was observed.
- Carbon Nano Structure materials from Cabot as conductive additive for Si anode was investigated.

CONTRIBUTORS AND ACKNOWLEDGMENTS

CONTRIBUTORS

Organization	Individuals	Facilities
Argonne	Wenqian Lu, Hyun-Woo Kim, Yan Qin, Caleb Colvay, Yeung D. Joo, Jin Kim, Devashish Salpoker, Steve Trask, Alison Dunlop, Bryant Polzin, Chen Luo, and Andrew Jansen	Electrochemical Power Service (EPS), Battery Manufacturing Facility (BMF), Center for Alternative Vehicle (CAV), Motor Engineering Research Facility (MERF), X-ray Imaging Facility (XIF)
DuPont Argonne	Chen Luo	
Facilities		Electrochemical Power Service (EPS), Battery Manufacturing Facility (BMF), Center for Alternative Vehicle (CAV), Motor Engineering Research Facility (MERF), X-ray Imaging Facility (XIF)

ACKNOWLEDGMENTS

Support from Project Faculty, Steven Dwyer, and David Head of the U.S. Department of Energy's Office of Vehicle Technologies Program is gratefully acknowledged.

Barriers and Challenges Slide Examples

Remaining Challenges and Barriers

- It is difficult to experimentally confirm the conductivity of novel materials due to the difficulties in finding procedures to create densified pellets on which impedance spectroscopy can be performed. For each material the high temperature stability has to be tested and sintering optimization has to be performed
- We still need to experimentally investigate electrochemical stability for some of the materials

REMAINING CHALLENGES AND BARRIERS

- High energy active material identification and acquisition remain a challenge.
 - Existing commercial active materials can't meet or exceed DOE/USABC goals.
 - Getting access to advanced active materials is not always successful.
- As a benchmarking activity, the focus of this work is to validate the performance of cell materials (including electrochemical and thermal properties).
 - Research efforts between the validation and research needs to be balanced.

Proposed Future Research

Instruction

- Proposed Future Research counts for 10% of your total project score.
- The title of this slide should make it clear that the slide shows your Proposed Future Research.
- Explain what you plan to do during the rest of this year (FY 2023) and next year (FY 2024). Provide justification for future plans.
- Add the statement to all slides with future-looking statements, “Any proposed future work is subject to change based on funding levels.”
- Be as specific as possible; avoid blanket statements.
- Highlight upcoming key milestones.
- Address how you will deal with any future decision points during that time and any remaining issues or barriers, including any alternative development pathways under consideration to mitigate risk of not achieving milestones.

Future Work Slide Examples

Hquest **Graphene-Enriched Hierarchical Polymer Additives Derived From Natural Gas**
 PI: George Skoptsov | H Quest Vanguard, Inc., Pittsburgh, PA | DE-SC0021767 | MAT255

Overview
 Timeline and Budget: Project start date: 08/04/2021, Project end date: 02/23/2022, Total funding: \$206,500, Percent complete: 80%
 Barriers and Technical Targets: Material Technical Team Technical Targets: 50% mass reduction of recycled carbon fibers (recycled carbon fibers) (short-term objective long-term), USDOE Target 2025 - 25% weight reduction (Gdwr) < 50%
 Partners and Collaborations: Project Lead: H Quest Vanguard, Inc., Collaborator/Sub: Penn State University, PI: George Skoptsov, Dr. Bandy Vardar-Wal, Co-PI: H Quest Vanguard, Inc., Carbon Conversion, Inc.
 In-kind support: Carbon Conversion, Inc. (provided samples of rCF)

Technical Approach
 Key Idea: Rapidly process cheap recycled carbon fiber in a microwave plasma reactor to improve mechanical strength of low-cost thermoplastic composites.
 Process: Thermoplastic polymer film is drawn and impregnated with the fiber surface and then deposits high surface area carbon (graphene) with recycled carbon fibers.
 Impact: Targeted tensile strength improvements of 20% - 100% would enable low-cost recycled carbon fiber composite parts to meet pre-performance requirements of automotive industry.

Microwave plasma: rapid thermochemical process
 Rapid thermochemical heating, Continuous, high-throughput processing, Minimal start-up/shut-down, No process CO₂ emissions, Flexibility in feedstocks and products, Compact, low-capital investment.

Summary
 The demonstrated approach can significantly improve mechanical properties of thermoplastic composites with use of a novel hierarchical, novel reinforcement fiber (rHF).
 The microwave surface of a recycled carbon fiber (rCF) is associated with a high surface area, porous structure and high BET surface area that improves the mechanical properties of the fiber and the composite, their strength metrics in low-cost thermoplastic matrix.
 In-kind products demonstrated capabilities (rCF) as a recycled carbon fiber additive, synthesized from polymer reinforcement feedstocks (textile or higher plastic) in a microwave plasma process.
 Unlike other carbon nanomaterials such as nanotubes or graphene sheets, production of which requires use of catalysts and slow carbon vapor deposition systems, rCF is formed rapidly under conditions of microwave plasma. The matrix continues to be improved, low cost processing (30-50% faster) and of equipment.
 The proposed effort of producing the cheap carbon fiber with rCF would significantly exceed their strength requirements to address.
 The significant increase in ultimate tensile strength (targeted 50% - 100%) of the CF reinforced thermoplastic parts with rCF would increase in cost is proportional to value added by the automotive industry, promote lightweighting, and improve circularity of carbon fiber materials.

Accomplishments
 Near-instantaneous exposure to microwave plasma heats cheap recycled carbon fibers to ~1500C and thermochemically modifies the surface, separating filaments, gently etching them, and depositing nanoscale high-surface area carbon structure with graphitic components.
 Overall, the process increases the carbon fiber surface area by ~ 10x as measured by BET.
 Accurately recycled carbon fiber (recycled carbon fiber) (short-term objective long-term), reducing surface area and increasing strength of the filaments.

Future Steps
 Scale-up the microwave plasma treatment system and process: Increase capacity from < 20 g to > 1 kg, Make continuous rather than batch processing, Establish process-product parameter relationships.
 Scale-up composite preparation and properties evaluation: Systematic evaluation of composite properties and repeatability/consistency at lab scales (> 1g) across multiple low-cost thermoplastics (HDPE, Nylon, etc), Evaluate and optimize fiber/composite property relationships.
 Pilots with carbon fiber and composite companies: Secure technology commercialization paths, Contract revenues and R&D synergies.

Future Scope Expansion
 Improve circularity of automotive tires.
 Microwave plasma treatment to restore the reinforcement properties of recycled carbon blacks (rCBs) by removal of polymer remnants and surface functionalization.
 Recycled carbon blacks (along with polymers, process aids, and fillers) are recovered after pyrolysis of end-of-life tires compounds.
 The pyrolysis changes the surface chemistry of the original carbon black, reducing reinforcement properties. Today, rCB cannot replace virgin carbon blacks.

Future Scope Expansion

Improve circularity of automotive tires.
 Microwave plasma treatment to restore the reinforcement properties of recycled carbon blacks (rCBs) by removal of polymer remnants and surface functionalization.

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Tire pyrolysis changes the surface chemistry of the original carbon black, reducing reinforcement properties. Today, rCB cannot replace virgin carbon blacks.

Proposed Future Work

- Experimentally investigate predicted conductivity for the novel conductors by creating densified pellets whenever possible
- Investigate optimal carrier doping for the novel conductors
- Investigate electrochemical and chemical stability of novel conductors
- Develop (with Mary Scott) local microprobe technique to assess Li-ion conductivity at an earlier stage in the development process.

"Any proposed future work is subject to changes based on funding levels."

Mandatory Summary Slide

- Summarize the key points you wish the reviewers and the audience to take away from your presentation.
- For those projects that are working toward specific technical targets, include a Summary Table summarizing key technical results to date in FY 2023 compared to FY 2022 results and the technical targets.

Argonne NATIONAL LABORATORY

ELECTRODE PROTOTYPING ACTIVITIES IN ANL'S CELL ANALYSIS, MODELING AND MANUFACTURING (CAMP) FACILITY

Project ID: BAT030

Overview

Timeline

- Start: October 1, 2014
- Finish: September 30, 2023

Budget

- FY22 - \$800K
- 100% DOE-EERE-VTO
- Partners: MERF, EADL, APS, CNM, PTF, universities, and industries

Barriers

- Development of PHEV and EV batteries that meet or exceed DOE/USABC goals – safety, cost-effective, sustainable, and has long cycle life

Relevance

- Transition new high energy battery chemistries invented in research laboratories to industrial production through independent validation and analysis in prototype cell formats.
- xx3450 & xx6395 pouch cells; ranging from 20 to 3,000 mAh capacity.
- Researchers are often not able to provide the quantities of novel materials needed to make a full-size EV cell to demonstrate the merits of their discoveries. The CAMP Facility is specifically designed to explore new materials with quantities as small as 50 grams for active materials, and even less for electrode/electrolyte additives.

Approach

- Researchers submit materials with promising energy density
- Small hand-coated electrodes are made
- Coil cells are made and tested
- Large material samples are obtained (MERF, galvanostatic, etc.)
- Coil lengths of electrodes are made from coated materials
- Pouch cells are made and tested
- Extensive diagnostics & electrochemical modeling of electrode/electrolyte systems

Progress

Multi-functional Coater

Developed High Quality Coatings During Factory Acceptance Test

2.3 mAh/cm² at 0.5 m/min using uniform thin coatings using the slot die coating head

Verified functionality of:

- Interchangeable coating heads
- IR drying system
- Corona treatment
- Progressive cavity pump

Graphite slurry on copper foil

Al₂O₃ w/ PVDF on substrate

Progress

Multi-functional Coater Installed in Dry Room

Coating system greatly enhances adaptability for coating various materials.

Hybrid ceramic polymer electrolyte composite membrane

Promising Next-Gen anodes and cathodes

Solid-state electrolyte materials

Traditional energy storage materials

Advanced interchangeable coating head system

Electrode-Ceramic Structure Coatings

Produced >10 meters of electrode-ceramic films (1 to 3 mAh/cm²) using roll-to-roll Coater

Polymer electrolyte (PE)

Coatings: LFP (10h), C (4h), Ni (1h), Pt (1h)

Assets: LTO (1h), C (4h), Ni (1h), Pt (1h)

• AIBN added to the PE (initiator)

• Obtained well dispersed slurries with PE (diluted with NMP)

• Uniform films were applied to the carbon-coated Al (cc-Al) foil via reverse comma coating method.

• Polymerization was initiated during 5-minute heat treatment; final curing step was completed in a convection oven.

See BAT028

X-ray Methodologies to Quantify Electrode Expansion

Developed X-ray methodologies to quantify electrode expansion in NMC811/Li cells

• During charge, Li⁺ ions are deposited on the Li which expands and pushes the NMC811 cathode against the spring.

• During discharge, Li⁺ ions are stripped from Li, releasing pressure on the spring.

• NMC811 and PE edges move together indicating that the separator is not compressed. The movement is solely because of expansion and contraction of the Li metal.

The irreversible expansion (drift) is 11.3 μm per cycle, or 34 μm for 3 cycles!

Progress

Materials for Diversifying Supply Chains and Increasing Sustainability

LiNi_{0.90}Mn_{0.05}Co_{0.05}O₂ (MERF & RNGC)

- Produced high quality slurry dispersion using high pH LNO-based oxide powder by mitigating gelation using slow order of addition process and temperature control
- Evaluated in 1.5 Ah pouch cells.

see BAT167, BAT251, BAT252, BAT253

LiMn₂Ni₂O₄ (commercial)

Full Cell Impedance Performance

90 wt% LFP (made by MERF)

5 wt% Tinized Cu

5 wt% Solvay S10 PVDF Binder

Coating Thickness: 50 μm

Total Coating Loading: 18.88 mg/cm²

Total Coating Capacity: 2.05 g/cm²

Area Capacity: 2.05 mAh/cm²

Area to Graphite Ratio: 1.0

LFP powder prepared via hydrothermal process

• 5V spinel electrodes with single wall carbon nanotubes (SWCNT) show lower cell impedance

see BAT252

• 100% Mn, Co-free baseline powder for Earth-Abundant Cathode Active Materials (EaCAM)

84 wt% LMR-NM

8 wt% Tinized Cu

8 wt% Solvay S10 PVDF Binder

Coating Thickness: 50 μm

Total Coating Loading: 11.45 mg/cm²

Total Coating Capacity: 2.05 g/cm²

Area Capacity: 2.05 mAh/cm²

Area to Graphite Ratio: 1.0

see BAT251

• 30 mAh pouch cells (LFP/Gr) assembled and testing still in progress

Summary

Developed methods to coat electrode-ceramic structure coating with roll-to-roll reverse comma coater in the dry room and produced >10 meters of these advanced films with loading targets ranging from 1 to 3 mAh/cm².

Installed the multifunctional coater in the CAMP Facility dry room.

Studied X-ray methodologies to quantify electrode expansion in NMC811/Li cells.

Provided advanced prototype electrodes in the Electrode Library by producing >100 meters of anodes and cathodes (baseline and novel materials) in support of various DOE battery programs.

Produced high quality electrodes using LNO_{0.90}Mn_{0.05}Co_{0.05}O₂ powder by mitigating gelation and produced 1.5 Ah pouch cells.

Produced electrodes using powders relevant to domestic supply chain and environmental sustainability, provided by RNGC (LMR-NM) and MERF (LFP).

Supplied numerous experimental electrodes and cells to DOE programs.

247 cells (FY21) 146 cells (FY22 as of April 2022)

Acknowledgment: funding from the U.S. Department of Energy's Office of Vehicle Technologies is gratefully acknowledged.

Summary Slide Examples

Summary

Work from this program has produced advancements towards understanding and achieving economically-viable, Mn-rich cathodes as alternative, earth-abundant oxides by:

- Systematic studies that separate bulk vs. surface contributions to low SOC impedance in Li/Mn- rich electrodes
- Correlating local ordering, related to composition, to bulk processes the influence low SOC impedance
- Verification of how voltage hysteresis mechanisms effect low SOC impedance response
- Development and verification of novel surface treatments that enable stable, long-term cycling of cobalt-free, Mn-rich compositions, at higher energies than state-of-the-art NMC-622, under standardized protocols in graphite cells
- Discovery of a new class of disordered, lithiated spinel cathodes that are based on MnNi compositions, are cobalt free, and can deliver significant capacities – these new materials may have important implications for understanding oxygen redox in complex oxides
- Correlating theory with experiment to elucidate mechanisms of voltage hysteresis that can occur in the absence of oxygen redox in over-lithiated oxides
- Elucidated effects of particle microstructure on the impedance of Li/Mn- rich electrodes via experiment & modeling
- Systematic investigation on the effect of various synthesis parameters on the resulting morphology of Mn-Ni precursors with on-going computational analysis to provide understanding on greater synthetic control of product

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1,807 sheets (FY21) 923 sheets (FY22 as of April 2022)

- Produced high quality electrodes using LiNi_{0.90}Mn_{0.05}Co_{0.05}O₂ powder by mitigating gelation and produced 1.5 Ah pouch cells.
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247 cells (FY21) 146 cells (FY22 as of April 2022)

Acknowledgment:
Funding from the U.S. Department of Energy's Office of Vehicle Technologies is gratefully acknowledged.

Questions?

Contact us by email:
VTAMR@ORAU.org